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A SURVEY OF ANALOG-TO-DIGITAL CONVERTER TECHNOLOGY FOR RADAR APPLICATIONS

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A survey of state-of-the-art analog-to-digital converters (ADCs) was conducted in 1990. The sampling rates are compared for ADCs that have from six to eighteen bits of resolution. These ADCs are graphically compared to the best ADCs of 1978 and 1981 as well as to the ADCs expected in 1992. This helps quantify the rate of progress of ADC technology.

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A SURVEY OF

ANALOG-TO-DIGITAL CONVERTER TECHNOLOGY

FOR RADAR APPLICATIONS

I. INTRODUCTION

The ever increasing speeds and dynamic ranges of modern radar signal processors require the use of state-of-the-art Analog-to Digital Converter (ADC) technology. In fact, many radar designs are constrained by the lack of ADCs with sufficient speed and/or dynamic range. Several trends in modern radar design are now stressing ADC technology more than ever. For example, the multiple adaptive beams of some phased array radars are now being formed by the radar signal processor. In this arrangement one or two ADCs are required for each element or subarray of the antenna. This huge increase in the required number of ADCs per radar now makes the size, power, and cost of an ADC critically important. Furthermore, the desire to sample at radar IF frequencies to digitally compute the in-phase and quadrature baseband signals can increase ADC speed requirements by 400% or more. The higher bandwidth waveforms sought by some radar designers will also raise ADC speed requirements. Coupled with these new ADC speed requirements is the requirement for more ADC dynamic range to enable processors to detect reduced signature targets in heavy clutter and ECM environments. As a result of these trends in modern radar design, renewed attention has been focused on ADC technology as it is often the limiting factor in overall system performance.

The purpose of this report is to present the results of a survey of state-of-the-art ADCs. ADC technology surveys were also conducted in 1978 and 1981 by KTP-3 [1,2]. Current state-of-the-art ADCs (1990 vintage) are graphically compared in this report to the best ADCs of 1978 and 1981 as well as to the ADCs expected by 1992. This should help quantify the progress that has been made in ADC technology over the last decade and enable the reader to guess at the pace of future ADC technology progress.

II. ANALOG-TO-DIGITAL CONVERTER SURVEY

The information on currently available ADCs was obtained by an exhaustive telephone survey of known ADC vendors, journal articles, and advertising literature [4,5]. The ADCs chosen for this report have sample rates ranging from 100 kHz to 500 mHz and resolutions of 6 to 18 bits. A vendor may feature several ADCs of the same word length but with various maximum sample rates. Only the vendor's fastest ADC at each word length was included in this report. ADCs were also excluded from this report if their

sampling rates were less than one-tenth of the industry average sample rate of ADCs with the same word length. Information on ADCs meeting these criteria was obtained for the 25 manufacturers listed in Table 1.

TABLE 1. ANALOG-TO-DIGITAL CONVERTER MANUFACTURERS

1. Advanced Analog	10. DCS/STL	18. Plessey
2. Analog Devices	11. ILC Data Device	19. Siemens
3. Analogic	12. ITT	20. Sipex
4. Burr-Brown	13. MEDL	21. Sony
5. Catalyst Semiconductor	14. Micro Power Systems	22. STC
		23. Tektronix
6. Comlinear	15. MicroNetworks	24. TRW
7. Crystal/Gould	16. Motorola	25. Westinghouse
8. Datel	17. Panasonic	
9. DCS		

A graphical presentation of the ADCs available in 1990 is shown in Figure 1. The word length in bits is plotted against the maximum sampling rate in units of Mega Samples Per Second (MSPS). The data points of Figure 1 are surrounded by a performance envelope which will be used in later figures to show ADC technology progress.. The manufacturer's name, part number, and maximum sampling rate of these ADCs are listed in Table 2. The ADCs in Table 2 without part numbers are non-commercial parts and are generally only for the company's private use.

The maximum sampling rates for this group of ADCs is quite impressive. All of the 6 to 10 bit ADCs have sample rates of 30 MSPS or higher. The fastest ADCs of this group are represented by a 500 MSPS 8 bit ADC from Tektronix and a 500 MSPS 6 bit ADC from Analog Devices. At 20 MSPS, Comlinear has the fastest 12 bit ADC. It is followed by no less than seven 10 MSPS 12 bit ADCs. Analog Devices now has a 14 bit ADC at the 10 MSPS rate. Also, 15, 16, and even 18 bit ADCs are available at speeds greater than .1 MSPS.

There are two trends in ADC technology that have become more dominant now than in the past. The first trend is the miniaturization of ADCs. Most ADCs suitable for radar applications are now either monolithic or small hybrid packages. In the previous two surveys many of the ADCs were composed of multiple boards or even an equipment rack of boards. Generally, the 6-11 bit ADCs are now monolithic and the 12-18 bit ADCs are hybrids. Most of the ADCs in this survey are smaller than the size of a small board. Thus, today's radar designer often has the option of selecting an ADC more for its performance than by its packaging. The second trend is that many ADCs now include

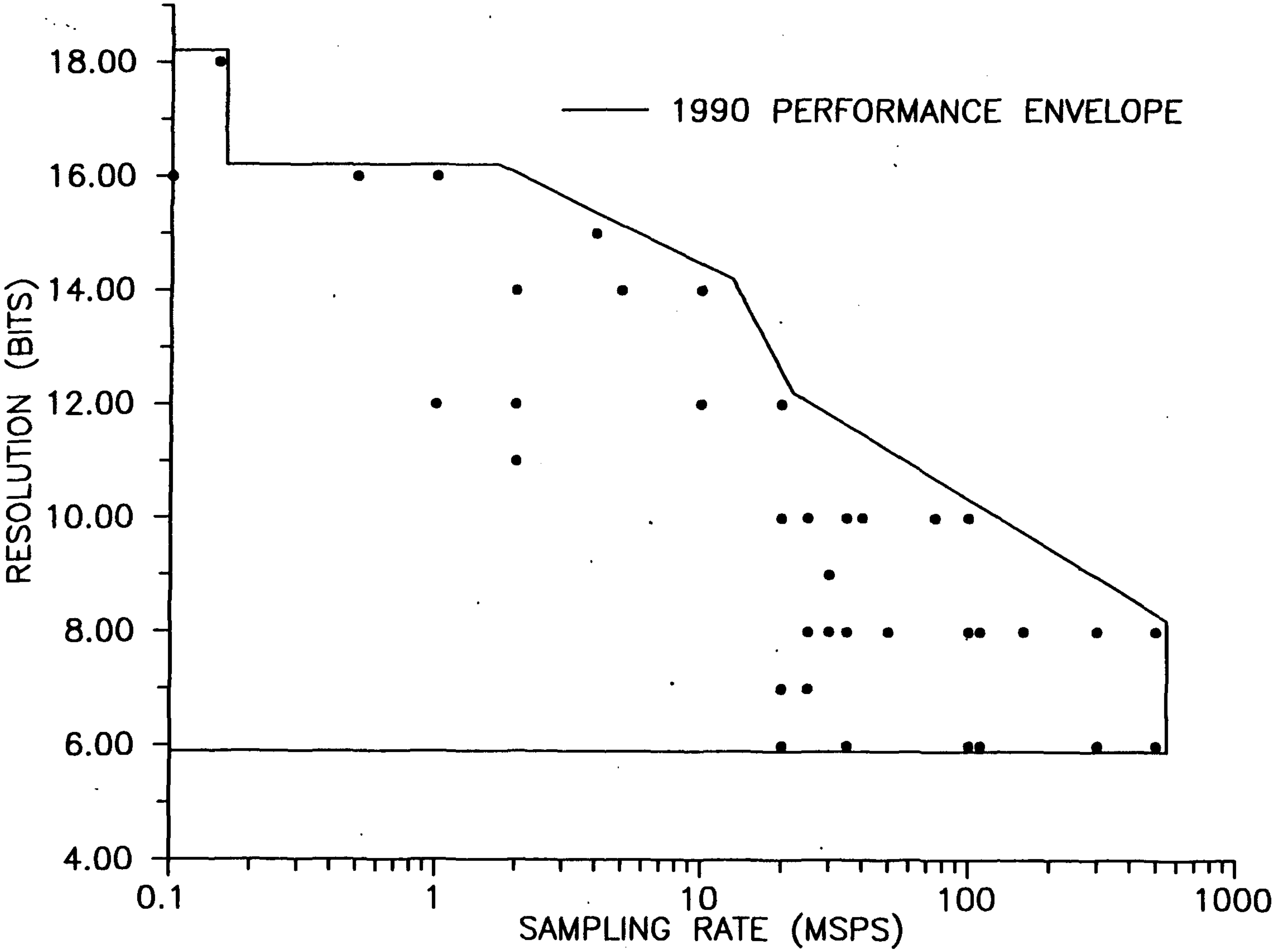

FIGURE 1. 1990 A/D CONVERTERS

TABLE 2. 1990 ANALOG-TO-DIGITAL CONVERTERS

RESOLUTION (BITS)	MANUFACTURER/PART NUMBER		MAXIMUM SAMPLING RATE (MSPS)
18	Analogic	ADC5020	.144
16	Analogic	ADC4344	1.0
16	Burr-Brown	ADC701	.5
16	Datel	ADS930	.5
16	Analog Devices	AD1377	.1
15	Westinghouse	N/A	4
14	Analog Devices	AD9014	10
14	Westinghouse	N/A	5
14	Analogic	ADC3110	2
14	Datel	ADS942	2
12	Comlinear	CLC936	20
12	Analog Devices	AD9005	10
12	Burr-Brown	ADC603	10
12	Datel	ADS130	10
12	ILC Data Device	ADC-00110	10
12	MicroNetworks	MN6300	10
12	Sipex	SP9560	10
12	TRW	TH1202	10
12	Catalyst Semiconductor	CAT5412	2
12	Advanced Analog	ADC5245	1
12	Crystal/Gould	CS5412	1
11	Micro Power Systems	MP7685	2
10	Tektronix	N/A	100
10	Analog Devices	AD9060	75
10	Micro Networks	ASA1040	40
10	Panasonic	AN6869	35
10	Comlinear	CLC920	25
10	Datel	ADC310	20
10	TRW	TDC1020	20
9	TRW	THC1049	30
8	Tektronix	TKAD10C	500
8	Analog Devices	AD9038	300
8	Sony	CXA1176AK	300
8	Datel	ADC 32/33	160
8	Plessey	SP97508	110
8	Micro Networks	MN5901	100
8	Siemens	SDA 8010	100
8	Sipex	SP1078	50
8	TRW	TDC1025	50
8	Micro Power Systems	MP7688	35
8	Panasonic	AN6857	35
8	ITT	UVC3130	30
8	Motorola	MC10319	25
7	Motorola	MC10321	25
7	Datel	ADC207	20
7	TRW	TDC1047	20
6	Analog Devices	AD9006	500
6	Micro Networks	MN5900	300
6	Siemens	SDA8200	300
6	Plessey	SP9756	110
6	TRW	TDC1029	100
6	Micro Power Systems	MP7686	35
6	Panasonic	AN6856	35
6	Datel	ADC-207	20
6	Sony	CXD1172	20

internal sample-and-hold circuitry. The purpose of sample-and-hold circuitry is to instantaneously sample the input voltage and hold it at a constant level while the ADC converts the voltage to a digital representation. Therefore unlike previous surveys, this report does not include a survey of stand-alone sample-and-hold devices.

As part of the survey, manufacturers were asked to predict the new ADC products that they were likely to produce in the next 12 to 18 months. The ADCs that are close to or exceed the 1990 performance envelope are shown in Figure 2. The number of manufacturers independently working to produce an ADC with the same specifications is shown in parentheses, if more than one is involved. Manufacturer names are not listed as anonymity was often requested. Exciting 1992 ADC projections include a .1 MSPS 24 bit ADC, a 10 MSPS 16 bit ADC, a 30 MSPS 14 bit ADC, a 250 MSPS 10 bit ADC, and a 1000 MSPS 7 bit ADC.

In order to assess the technology progress of the last decade, the ADC performance envelopes of 1978, 1981, and 1990 were plotted in Figure 3. The 1978 and 1981 performance curves were determined by the best monolithic, hybrid, and small board based ADCs as reported by the earlier KTP-3 surveys. Very measurable progress in speed and resolution can be observed from Figure 3. Figure 3 shows that the most dramatic progress for the three years between 1978 and 1981 occurred for the 8 to 12 bit ADCs. During the 9 years between 1981 and 1990 the most progress was made in the 12 to 18 bit ADCs.

Table 3 lists the ADCs that have been technology benchmarks in the past as well as those of 1990 and those projected for 1992. Table 3 gives the speed in MSPS of the fastest ADCs of the years of 1978, 1981, 1990, and 1992. Each ADC listed represents the fastest ADC available for its resolution and year. In addition, a listed ADC had to be faster than all ADCs of greater resolutions. The large multiboard ADCs of 1978 and 1981 are listed separately in the last two columns. The multiboard ADCs were excluded from the technology progress comparisons of the first four columns as their performance is determined as much by size and cost allocations as the employed monolithic and hybrid ADC technology. Where applicable, the percentage increase in speed of an ADC compared to the previous column is given in parenthesis. The average of these percentage increases in speed for each year is given near the bottom of the table. The average annual percentage rate of speed increase is shown at the bottom of Table 3. It is interesting to note that during the latest period of time, 1981 to 1990, the average yearly increase in ADC speed was only 17%. In contrast, the average yearly increase in speed during the 1978-1981 period was 135%. The low 17% growth rate would have been worse if this survey had been conducted in 1987. In fact this survey was purposely delayed after a preliminary 1987 survey showed a surprising lack of ADC

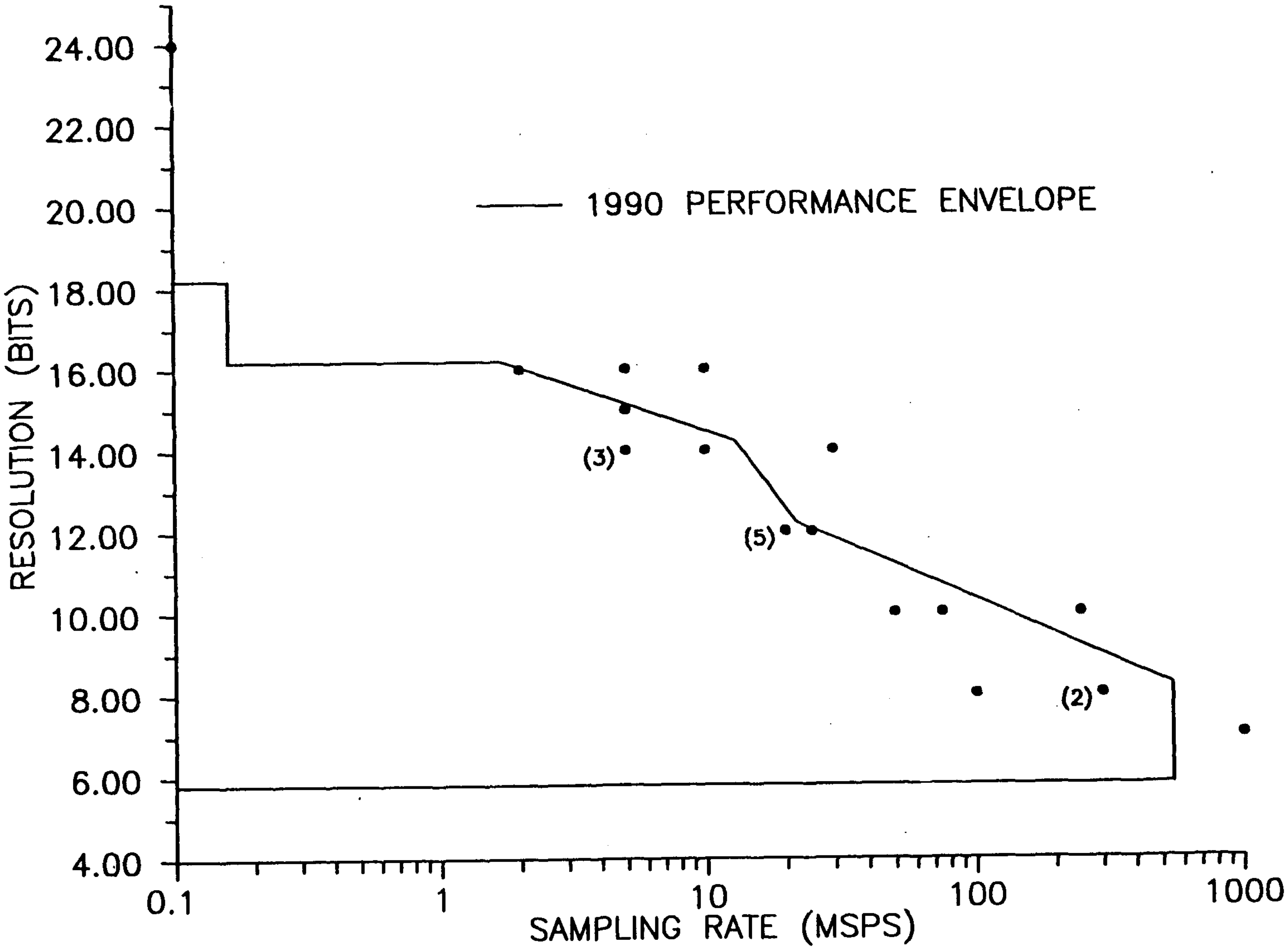

FIGURE 2. 1992 A/D TECHNOLOGY PROJECTION

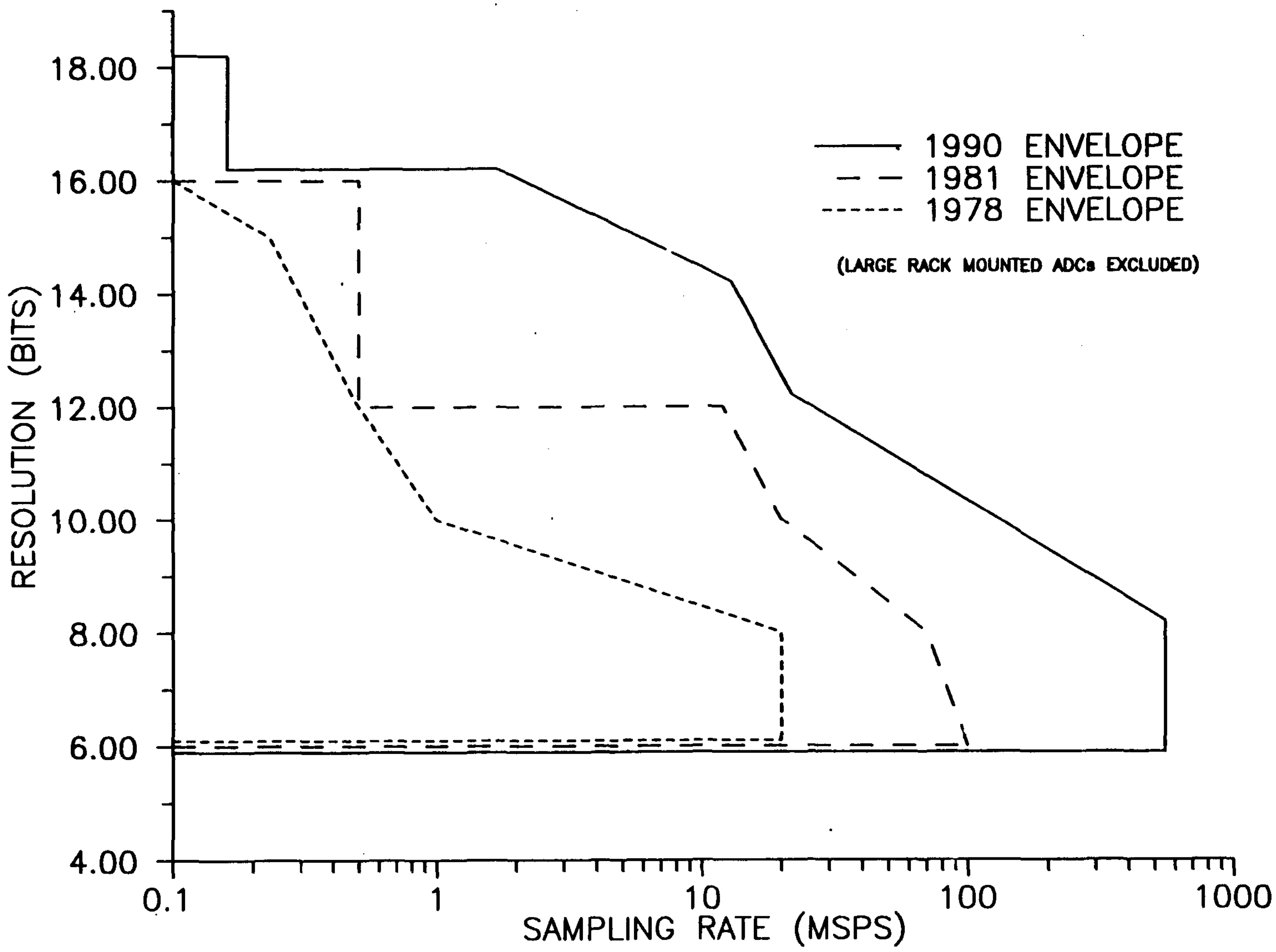

FIGURE 3. A/D CONVERTER DEVELOPMENT HISTORY

TABLE 3. A/D CONVERTER TECHNOLOGY PROGRESS

Resolution (bits)	1978 (MSPS)	1981 (MSPS)	1990 (MSPS)	1992 (MSPS)	1978 MULTIBOARD (MSPS)	1981 MULTIBOARD (MSPS)
24				.10		
18			.14			
16	.10	.50(400%)	1.0(100%)	10(900%)		
15	.23		4.0		.70	1.0
14			10	30(200%)		
13					10	10
12	.50	12(2300%)	20(70%)			
10	1.0	20(1900%)	100(400%)	250(150%)		
8	20	70(250%)	500(610%)		100	
7				1000		
6		100			500	
AVG SPEED INCREASE		1200%	300%	400%		
AVG ANNUAL SPEED INCREASE		135%	17%	124%		

development progress.[3] Delaying this survey until 1990 accommodated several recent ADCs which have significantly advanced the state-of-the-art. If the 1992 predictions are correct, a large average yearly speed increase of 124% will be experienced between 1990 and 1992. This would reverse the trend of declining progress in ADC technology development experienced between 1981 and 1987.

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